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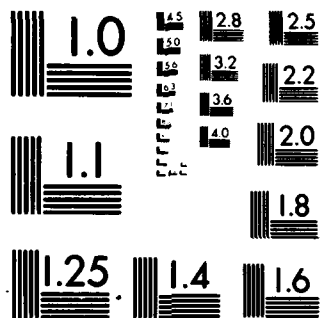
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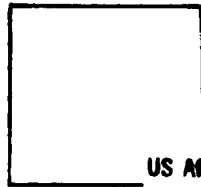
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CONSTRUCTION NORMS AND REGULATIONS: PLANNING
NORMS--DAMS MADE FROM EARTH MATERIALS

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CONSTRUCTION NORMS AND REGULATIONS: PLANNING
NORMS--DAMS MADE FROM EARTH MATERIALS

Edited by
L. G. Bal'yan

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CONSTRUCTION NORMS AND REGULATIONS: PLANNING NORMS--DAMS MADE FROM EARTH MATERIALS

Moscow STROITEL'NYE NORMY I PRAVILA in Russian Pt 2 Chap 53 1974 signed to press 26 Feb 74 pp 1-31

[Chapter 53, "Plotiny iz gruntovykh materialov" (Dams Made of Earth Materials) from Construction Norms and Regulations II-53-73, edited by L.G. Bal'yan, State Committee of the USSR Council of Ministers for Construction Affairs (USSR Gosstroy), Moscow, Stroyizdat, 1974, 40,000 copies]

ANNOTATION

[Text] The chapter of SNiP [Construction Norms and Regulations], II-53-73, "Dams Made From Earth Materials," was drawn up by the All-Union Scientific Research Institute of Hydraulic Engineering imeni V. Ye. Vedeneyev, and the Gidroyekt Institute imeni S.Ya. Zhuk of the USSR Ministry of Power and Electrification with the participation of the Gidromekhanizatsiya Trust of the USSR Ministry of Power and Electrification and its design office, Gidromekhproyekt. Used in compiling the chapter of SNiP were materials of the All-Union Scientific Research Institute of Water Supply, Sewer Systems, Hydraulic Engineering Structures and Engineering Hydrogeology of USSR Gosstroy, The All-Union Soyuzvodproyekt Association of the USSR Ministry of Land Reclamation and Water Resources, the Moscow Construction Engineering Institute imeni V.V. Kuybyshev of the USSR Ministry of Higher and Secondary Specialized Education and other organizations.

The enforcing of this chapter of SNiP on 1 January 1974 rescinds the chapters of SNiP (publications of 1963 and 1964):

- II-I.4-62* "Earthfill Dams. Planning Norms";
- II-I.5-62* "Hydraulic Earthfill Dams. Planning Norms";
- II-I.6-62 "Rockfill Dams. Planning Norms."

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Requirements for the Foundations of Dams, the Juncture of the
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5. **BASIC CONDITIONS FOR DAM ESTIMATES**

State Committee of the USSR Council of Ministers on Construction Affairs (USSR Gosstroy)	Construction Norms and Rules Dams Made of Earth Materials	SNiP II-53-73 Replacing SNiP chapters II-I.4-62* II-II.5-62* II-I.6-62
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1. GENERAL CONDITIONS

1.1. These norms extend to the planning of solid dams (or levees under pressure) made of earth materials (earthfill and hydraulic earth fill, earth and rockfill) included among installations of a varied range of construction (hydraulic power and water transport, reclamation systems, water supply systems, fish breeding, flood control).

Note: 1. When planning dams designated for construction in seismic regions, in the construction-climatic zone of the North, on settling, swelling and permafrost soils, as well as at sites subject to landslides, mud flows and karsts, consideration must also be given to the additional requirements imposed on the construction of structures under the given conditions, using as a guideline in this case the appropriate normative documents, approved by or coordinated with USSR Gosstroy.

2. The classes of dams are established in accordance with the chapter of SNiP on the basic conditions for planning hydraulic engineering river structures.

1.2. Engineering research (including geodesic engineering, geological engineering and hydrometeorological engineering) necessary for the planning and construction of dams made of earth materials should be done in accordance with the requirements of the chapter of SNiP on engineering research for construction, normative documents to determine the estimated hydrological characteristics and additional data contained in the assignments for planning, taking into consideration the specific conditions of the planned project.

Introduced by the USSR Ministry of Power and Electrification	Approved by the State Committee of the USSR Council of Ministers on Construction Affairs on 20 March 1973	Introduction deadline 1 January 1974
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1.3. Depending on the material of the dam embankments and their watertight devices, as well as the methods of erecting them, dams are subdivided into the following types (Table 1).

1.4. The dam site should be selected on the basis of a technical and economic comparison of the variants, in coordination with the layout of the water engineering system, and depending on the topographical and geological engineering conditions of the construction site.

Other conditions being equal, preference should as a rule be given to the dam site in the narrowest part of the river valley, formed by hard rocks.

To be taken into consideration here are:

- a) The need to place the structures for passage of water and fish so as to eliminate the possibility of dangerous erosions of the banks and undercutting of the dams when the water is discharged into the tailwater;
- b) The possibility of water passing through the dam site during the period of its construction, as well as the possibility of making roads for various purposes along the dam and at the approaches to it during the construction period as well as during the operational period;
- c) Including the fill (banquette) necessary to cover the river bed in the construction period of the water engineering system in the dam embankment;
- d) The conditions for the discharges and levels of the water flow, as well as the conditions for passage of ice, timber, ships and other special requirements made of the planned project.

1.5. The type of dam (see Table 1) should be selected with respect to the topographical conditions, the geological engineering conditions in the foundations and banks, the hydrological and climatic conditions, the amount of head pressure and the estimated maximal discharge of the water, the availability of local construction materials, the seismicity of the region, the conditions for passage of the construction discharges of water, the deadlines for putting the structure into operation and the operating conditions of the dam.

The type and design of the dam should be selected on the basis of a technical and economic comparison of the variants.

Note. The use of earth and rock obtained from useful excavations should especially be stipulated to erect dams made of earthen materials.

1.6. Dams made of earthen materials may be erected on both rocky and non-rocky foundation soils.

Notes: 1. Building dams on non-rocky soils of a foundation, containing watersoluble inclusions in an amount greater than indicated in section 2.3

Table 1. Types of Dams Made of Earthen Materials

Types of Dams	Materials		Methods of Constructing Dams
	Embankments of Dams	Impervious Devices	
1. Earthfill	Sand, coarse rubble or clayey	Clayey soils, fine sand, non-earthen materials, and turf	Dumping earth dry with subsequent compaction by mechanical means or dumping into water
2. Hydraulic earthfill	Same	Clayey soils, fine sand or non-earthen materials	Filling with soils by sluicing
3. Earth	Rock and coarse rubble soils	Clayey soils, fine sand or non-earthen materials	Dumping earth and rock. Soil is dumped dry with subsequent compaction by mechanical means or dumping in water
4. Rockfill	Rock	Non-earthen materials (concrete, reinforced concrete, bituminous concrete, synthetic films, etc.)	Dumping rock without compaction or with compaction by hydraulic or mechanical means

is permissible only with the appropriate substantiation; in this case various structural measures may be stipulated to prevent leaching of the soils of the foundation (for example, the installation of blankets, cutoffs, curtains, etc.).

2. Constructing dams made of earth materials on a turf (peat formation) foundation is as a rule permissible when the height of the dams is up to 20 m, with the degree of breakdown of the turf at least 50%. Higher dams, under these conditions, as well as dams on muddy foundation soils, may be erected only with the proper substantiation.

1.7. The requirements made of non-rocky foundation soils are as a rule analogous to those made of the soils of the embankment of earth dams. In the evaluation of the quality of the soils of a non-rocky foundation, particular attention should be given to the presence in it of:

- a) Piping soils;
- b) Soils in which, during the building of the dam, excess pore pressure may develop because of their consolidation.

1.8. In evaluating the quality of a rocky foundation, particular attention should be paid to the presence in it of:

- z) Cracks filled with fine fractions of soil, easily washed away;
- b) Tectonic disturbances (faults and slip faults);
- c) Weakened zones which may prove unstable and may be destroyed when they are saturated with water.

1.9. In the plans for dams of classes I, II and III, installation must be stipulated of a control and measuring device to carry out observations at the site of the work of the structure in the construction process and in the period of its operation; to evaluate the reliability of the project, discover defects promptly, designate repair measures, prevent disasters and improve the operating conditions. The observations should determine:

- a) Vertical (settling) and horizontal displacements of the dam embankment;
- b) Pore pressure in the clayey elements of the embankment of the dam and the foundation;
- c) Stresses in the embankment of the dam and the foundation;
- d) The quality of the work of the drain and watertight devices;
- e) The discharge of the water filtered through the dam and its foundation, as well as in the banks and places where the dam adjoins concrete structures;

f) The discharge of water seeping through the dam and its foundation, as well as in the banks and the places where the dam is adjacent to concrete structures;

g) The turbidity and temperature of the water which has filtered through and its chemical composition;

h) The seismic fluctuations.

With the appropriate justification, additional fullscale observations may be stipulated. For dams of classes II and III less than 30 m high, fullscale observations should be limited only to observations of the settling of the dam, the rate of water filtering through the dam and its foundation, the position of the depression surface in the embankment of the dam and the banks and the pore pressure in the embankment of the dam and the foundation.

1.10. The choice of the design and designation of the amount of control and measuring equipment, as well as its placement should be made with respect to the class of the dam, its design, the geological and hydrogeological conditions and the conditions for building and operating the dam.

1.11. The basic estimates pertaining to the planning of dams made of earthen materials should be made in accordance with the requirements of part 5 of this chapter.

1.12. When choosing the methods of working on the erection of the dam, the requirements of the chapter of SNiP on rules for performing and receiving work for earth structures should be taken into consideration.

Estimated Characteristics of Soils

1.13. When planning dams made of earth materials the following basic characteristics of soils should be assumed:

a) The granular composition of the soils;

b) The plasticity limit (flowability W_T and buildup W_p) and the maximum molecular specific water retention W_M ;

c) The specific gravity of the soil particles γ_s ;

d) The volume weight of the frame of the soil γ_{CK} ($\gamma_{CK.n}$ -- in a dense state and $\gamma_{CK.p}$ -- in a free flowing state);

e) The moisture content of the soils W ;

f) The seepage coefficient k_ϕ ;

g) The angle of internal friction ϕ ;

h) The specific cohesion C (with a slip C_c and break C_p) for clayey soils;

i) The consolidation coefficient a ;

j) The indices of the seepage strength of the soils (critical gradients: heaving of the weighting I_k^B , piping I_k^C and contact erosion I_k^{k-P}).

In addition, determination must be made of the content in the soils of water-soluble salts as well as organic impurities and the degree of their decomposition. For stone and coarse rubble soils, the water absorption and frost resistance should be determined.

1.14. When planning dams of classes I and II, in addition to the soil characteristics indicated in section 1.13, determination should be made of:

a) The temporary resistance of the soils to compression, the coefficient of softening of the parent rock for stone and coarse rubble soils;

b) Swelling, shrinking and sagging for clayey soils.

1.15. The characteristics of the soils of the embankment and foundation of dams made of earthen materials should be established from the data of the geological engineering and hydrogeological research, and of dams planned to be made from artificial mixtures of soils---by making special studies and experimental work.

1.16. The characteristics of the soils should be established by statistical processing of the experimental data, using as a guideline the requirements of the chapter of SNiP on planning the foundations of hydraulic engineering structures. The estimated value of the volume weight of the earthen frame (γ_{ck}) should be assumed as 90% for class I dams, 70% for class II, and 50% security for classes III and IV.

1.17. The characteristics of the soils for the building of hydraulic-fill dams should be established from the results of studies of the quarries of the planned dam and by analogy with dams built on run-of-quarry soils, according to the granular composition and form of the particles similar to the soils of the planned structure.

Experimental buildup should be stipulated when planning dams of class I, and for dams of classes II-IV---only with special justification.

Note. In the process of constructing hydraulic fill dams, determination must be made of the characteristics of the soils washed in, in order to define precisely their estimated amounts and to introduce (in the case of a deviation from the initially assumed characteristics of the soils) refinements in the estimates made of the dams.

Table 2. Estimated Values of the Physical-Mechanical Characteristics of Sandy and Gravelly Alluvial Soils

Soil	Volume weight of soil frame γ_{ck} , t/m ³	Interior friction angle φ , °	Seepage coefficient, k_f , m/day
Sand, dusty	1.40-1.50	24-28	0.5-5
Sand, fine and average	1.45-1.60	29-34	5-30
Sand, coarse	1.55-1.65	30-34	15-35
Sand, gravelly	1.60-1.75	32-35	20-50
Gravelly (rubble) soil with sandy fraction content under 30%	1.70-1.90	35-40	over 50

Notes: 1. Table 2 was compiled for soil with a specific gravity of 2.65-2.70 t/m³.

2. The higher of these values of the volume weight of the soil frame pertains to material with a rounded shape, the lower--to soil with nonrounded, sharp-edged grains.

3. The higher values of the interior friction angle and the seepage coefficient pertain to soils with sharp-edged grains, and the lower--to soils with rounded particles.

1.18. At the preliminary stages of planning the above-water sections of hydraulic fill dams made of sandy and gravelly (rubble) soils, the estimated physical-mechanical characteristics of the alluvial soil are first designated in accordance with the data of Table 2, with subsequent correction according to the actual indicators. The volume weight of the soil frame, if it is built up under water, should be assumed as the mean value of the volume weight of the soil according to Table 2, and the volume weight of the frame of the accepted soil is in a maximally free-flowing state.

1.19. For nonuniform hydraulic earthfill dams (section 3.1), the physical-mechanical characteristics of the alluvial soil should be assumed separately for each zone singled out in the structure of the dam.

1.20. The density of the soil in the embankment of the dam is expressed by the value of its volume weight of the frame, γ_{ck} , and the rubble--by the porosity value, n .

1.21. The density to which the soils of hydraulic earthfill, earth and rock-fill dams should be brought should be designated in consideration of:

- a) The nature of the material and its location in the dam embankment;
- b) The method of pouring the material and the intensiveness of erecting the dam;

c) The technical and economic indicators, which depend on the methods and degree of packing the soils.

1.22. For hydraulic earthfill, earthfill and rockfill dams of classes I and II, provision should as a rule be made for experimental pouring and rolling of the soils on large-scale models built in the section volumes of the planned structure, to verify the estimated characteristics of the soils in the dam embankment and the designated degree of consolidation.

The volume weight of the rock filling of earth and rockfill dams of classes III and IV may be designated approximately from the conditions of the porosity of the fill assumed for dams built with:

Pouring rock in layers in a thickness up to 2.5 m $n=0.20$ 0.25 ;

Filling rock in tiers in a thickness of over 10 m $n=0.35$ 0.40 ;

Lower values of n should be assumed for soils with varying granular size.

1.23. When designating the density of clayey soils in uniform earthfill dams of any height and dams with an upper impervious prism, as well as in dams with a core made of clayey soil, the density of the soil used may be stipulated as variable along the height of the dam, taking into consideration in this case its compression properties.

2. EARTHFILL DAMS

2.1. With respect to the structure of the dam embankment, their impervious devices and the methods of erection, earthfill dams are subdivided into the following basic types (Table 3).

2.2. When planning earthfill dams, along with the instructions in part 1, the following should be taken into consideration:

a) If the foundation is not rocky, preference should be given to dams made of homogeneous soil, dams with a core or soil facing; the use of dams with a facing or diaphragm made of rigid, non-soil materials is not recommended;

b) When building dams in two or several sections, preference should be given to variants of dams made of homogeneous soil with a facing (or an impervious upper prism).

Requirements for Materials

2.3. All types of soils may be stipulated for the embankment of earthfill dams, with the exception of:

a) Soils containing water-soluble inclusions of chloride or sulfatochloride salts in an amount over 5% or sulfate salts over 2% by weight;

Table 3. Types of Earthfill Dams

Distinguishing Features of Dams	Types of Dams
1. According to structure of the embankment of the dam (Fig. 1)	a) Made of homogeneous soil b) Made of nonhomogeneous soil c) With a facing made of non-soil materials d) With a facing made of soil e) With a core f) With a diaphragm (wall, sheet pile)
2. According to structure of the impervious devices in the foundation of the dam (Fig. 2)	a) With a blanket b) With a cutoff c) With a grout curtain d) With a diaphragm (wall, sheet pile)
3. According to method of erecting the dam	a) With mechanical packing of soil b) Without mechanical packing of soil (with the pioneer method of pouring dry or with pouring into water)

Note: The structures of impervious devices in the foundation of the dams shown in Figure 2 may be used for various types of earthfill dams, shown in Figure 1.

b) Soils containing incompletely decomposed organic matter (vegetation residues) in an amount by weight over 5% or completely decomposed organic matter in an amorphous state, in an amount by weight over 8%.

Note. The soils indicated in subpoints "a" and "b" may be used for the dam embankment with the appropriate justification and on condition that the necessary protective engineering measures are carried out.

2.4. The selection of materials for the embankment of the dam, including the impervious devices and drainage should be based on the data from appropriate studies of the soil and rock and should satisfy the requirements of the normative documents approved or in conformity with USSR Gosstroy.

2.5. To form the earthen impervious devices (faces, cores, blankets, cutoffs) almost impervious soils should be used (primarily clayey) with a seepage coefficient of $k_f \leq 10^{-4}$ cm/sec.

The following should be taken into consideration when selecting these soils:

a) The most suitable soils for forming impervious devices are clayey soils with a natural moisture content equal to or greater than the moisture content at the buildup limit, but less than the moisture content at the flowability limit;

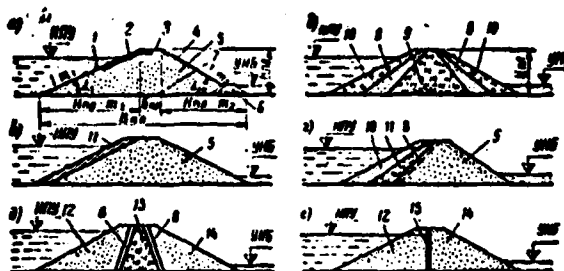


Figure 1. Types of Earthfill Dams (According to the Structure of the Embankment of the Dam)

a--made of homogeneous soil; b--made of nonhomogeneous soil; c--with a facing made of non-earth materials; d--with a facing made of soil; e--with a core; f--with a diaphragm (wall, sheet pile); 1--upstream slope; 2--shoring of slope; 3--crest; 4--downstream slope; 5--embankment of dam; 6--drain banquettes; 7--base; 8--transitional zones; 9--central prism; 10--protective layer; 11--facing; 12--upstream prism; 13--core; 14--downstream prism; 15--diaphragm; $H_{\text{пл}} m_1$ --upstream slope; $H_{\text{пл}} m_2$ --downstream slope; $b_{\text{пл}}$ --width of dam along the crest; $B_{\text{пл}}$ --same, along the bottom; $H_{\text{пл}}$ --height of the dam;
 $m_1 = \text{cig } a_1$; $m_2 = \text{cig } a_2$

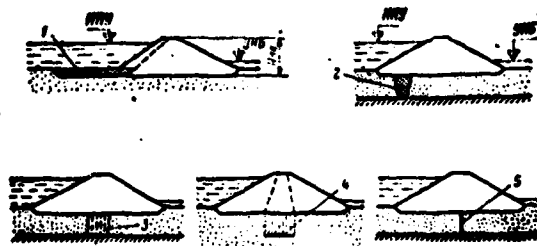


Figure 2. Structures of Impervious Devices in Foundation

1--blanket; 2--cutoff; 3--grout curtain; 4--same, suspended; 5--diaphragm (wall, sheet pile).

b) For faces and blankets of dams of classes III and IV up to 20 m high, peat with a degree of decomposition of 50% and more may be used;

c) To form impervious devices it is permissible to use an artificial soil mixture containing clayey, sandy and coarse rubble soils. The composition of the soil mixture should be determined from the results of appropriate studies and checks of it under production conditions at experimental pourings based on a technical and economic comparison of the variants.

2.6. For reverse filters, drains, transitional zones and slope shorings, it is permissible to use sandy and coarse rubble soils, as well as riprap, which should possess sufficient strength and frost resistance and should not contain water-soluble inclusions.

2.7. The use of sandy soils (fine, average and coarse) is permitted for uniform dams if the seepage resistance of the soils of the dam is ensured and the amount of the seepage rate of the water through the embankment of the dam is permissible according to the results of the water management and technical and economic estimates.

2.8. Sandy and coarse rubble soils may be used without restrictions for the downstream parts of the structure of all earthfill dams with the appropriate juncture of the downstream part of the dam and the basic section.

Configuration of the Slopes and Crest of the Dam

2.9. The gradient of the slopes of dams should be designated on the basis of the stability conditions, taking into consideration:

a) The physical-mechanical characteristics of the soils of which the slopes of the dams are formed and the soils of the foundation;

b) The forces exerted on the slopes (in addition to the forces of its own weight): seepage weighting of the water, capillary pressure, seismic, dynamic, various types of loads acting on the crest, etc.;

c) The height of the dam;

d) The work conditions for building the dam and operating it.

Notes: 1. In the preliminary designation of the slopes it is permissible to use analogous data of structures already built with the subsequent verification of the estimate of the stability of the slopes.

2. When the upstream slope of the dam has a face made of material with a lower value of φ and c than the corresponding characteristics of the soils of the main embankment of the dam, the upstream slope should be designated in consideration not only of the possibility of the slope as a whole sliding, but also of the slipping of the face along the surface of the slope and the slipping of the protective layer on the surface of the facing.

2.10. The installation of berms on the slopes of the dams should be stipulated, determining their number in relation to the height of the dam, the work conditions, the types of shoring for the slope and its overall stability.

The berms should be provided on the upstream slope at the end of the shoring to create the necessary support, and on the downstream slope--for service passageways and collecting and removing the storm waters.

Installation of the berms should not result in an overall diminishing of the gradient of the slope as opposed to that determined by the estimate.

2.11. The width of the crest of the dam should be established in relation to the work and operation conditions (using the crest for a passageway, thoroughfare and other purposes), but should be at least 3 m.

Note. The width of the crest of the dam in places adjoining other structures or the banks should be established in accordance with the structure of the join and the purpose of the areas created.

2.12. The elevation of the crest of dams should be designated in consideration of its rise above the estimated water level.

The rise of the crest of the dams, h_2 , is determined from the two estimated cases of the water level in the tailwater:

- 1) The normal backwater level (NPU);
- 2) The augmented backwater level (FPU) of the estimated provision for security.

The rise of the crest is determined with respect to the wind surge of the water, Δh , and the height of the runup of the windblown waves, h_H , the estimated provision for security, and the necessary reserve, a , along the height of the structure, according to the formula

$$h_2 = \Delta h + h_H + a \quad (1)$$

The elevation of the crest of the dam should be designated for a less favorable estimated case.

The height of the runup of the windblown waves and the height of the wind-blown surge of the estimated provision for security are determined according to the normative documents for planning hydraulic engineering structures exposed to waves.

If the estimated maximal water discharge passes with a lower water level near the dam, the estimate should be made in accordance with section 2.12, only for the first estimated case.

2.14. The reserve along the height of the dam (see section 2.12), regardless of its class, should be calculated for all dams, the destruction of which may cause a disaster. The reserve should be at least 0.5 m.

Note. When the magnitude of the windblown surge of the water is very low or when the magnitude of the run-up of the windblown water and the surge of the water adds up to a value less than 0.5 m, the rise of the crest of the dam, regardless of its class, should be at least 0.5 m.

2.15. When the crest of the dam has an impervious, strong, stable parapet, the rise of its top should be determined in accordance with section 2.12, like the elevation of the crest of the dam. In this case the rise of the crest of the dam, regardless of its class, above the normal backwater level should be not less than 0.3 m, and with the passage of the estimated maximal water discharge, the elevation of the crest of the dam should be no lower than the corresponding static water level.

2.16. When there are roads on the crest of the dam and when there is no parapet on the headwater side, barriers or other safety devices should be constructed in accordance with the norms for planning highways.

2.17. If the crest of the dam is made of clayey soils, provision should be made for covering it with a protective layer made of sandy or gravelly (rubble) soil. The thickness of the protective layer, including the thickness of the covering, should be designated in accordance with the norms for planning the foundations of buildings and structures no less than the depth of the seasonal freezing of the ground in the given region.

Shoring of the Slopes

2.18. The slopes of earthfill dams should be protected by special shorings, calculated for exposure to waves, ice, flows of water, precipitation and further climatic factors and factors destructive to the slope (penetration by burrowing animals, swelling of clayey soil in winter, etc.).

2.19. The following types of shorings may be stipulated for the protection of the upstream slope (according to the basic type of materials used):

- a) Rock (fill);
- b) Concrete monolithic, reinforced concrete precast and monolithic with ordinary and prestressed reinforcement;
- c) Asphalt concrete;
- d) Biological.

Also permissible, if there are data substantiated by studies or construction and operation experience, is the use of other types of light shorings for the upstream slopes, as for example, gravel-pebble, soil-cement, etc.

2.20. The type of shoring should be determined on the basis of technical and economic evaluations of the variants, taking into consideration the maximal

utilization of mechanized devices and local materials, the nature of the soil of the dam embankment, the corrosiveness of the water and the life of the shoring under the operating conditions.

2.21. The shoring of the upstream slope of the dam is divided into the basic, placed in the zone of maximal wave and ice action occurring during the operating period, and light—lower and higher than the basic shoring, right up to the crest of the dam.

2.22. The upper limit of the basic shoring should as a rule be considered the elevation of the crest of the dam.

If the crest rises considerably over the estimated water level, the basic shoring should end below the crest at the level of the height of the run-up, $h_{\text{п}}$; light shoring reaches farther up to the crest.

The lower limit of the basic shoring should be designated at a depth of $H_{\text{г}} = 2h_{1\%}$ (where $h_{1\%}$ is the height of the wave for a 1%-provision of security), counting from the minimal level of the available capacity of the reservoir.

In this case the lower limit of the basic shoring should be below the under-water lip of the ice sheet with its estimated thickness and minimal level of available capacity of the reservoir at a value equal to half the thickness of the ice sheet.

The lower limit of the light shoring is determined by the depth of the reservoir at which the value of the wave rates does not exceed the rate of touching of the particles for the given soil of the slope.

If the shoring of the bottom is installed before the structure, the light shoring of the slope of the dam should be firmly joined to it.

2.23. In designating the lower limits of the basic and light shoring, the action of the water on the slope of the dam and the ice conditions of the reservoir when it is being filled should be taken into consideration.

2.24. When joining the basic and light shoring, structural measures must be stipulated in the form of a support made of rock or concrete. The dimensions of the support should be designated in relation to the slopes and their height, as well as the coefficient of friction of the covering where the support comes into contact with the material of the slope, taking into consideration the rise of the covering under exposure to waves.

2.25. Unsorted rock should as a rule be used for the shoring of slopes with rock fill. The use of sorted rock is permitted with the proper justification.

2.26. The necessary weight and sizes of the individual rocks in the fill for the shoring of the slopes, the number of rocks smaller than estimated, and the thickness of the fill should be determined by calculation in accordance

with the requirements of the normative documents for planning hydraulic engineering structures exposed to waves.

Note. For preliminary calculations the thickness of the rock fill made of unsorted rock should be at least $3D_m$, and with sorted rock--at least $2.5D_m$, with D_m --the diameter of the rock in meters, relative to the diameter of the sphere, which may be determined by the relationship

(2)

where Q is the estimated weight of the individual rock in the fill in tons;
 γ_k is the volume weight of the rock in t/m^3 .

2.27. The thickness of the rock fill should be taken in consideration of the possibility of partial removal of the fine particles from the fill with wave action, the movement of large rocks, some compaction of the shoring material and the operating experience of analogous shorings.

2.28. Rock materials for slope shorings should be made from strong igneous, sedimentary and metamorphic rock with the necessary strength, frost resistance and water resistance, satisfying the requirements of the chapter of SNiP 1-B, 8-62, "Materials and Items Made From Rock."

2.29. Monolithic reinforced concrete shorings for slopes should as a rule be stipulated for the slope of dams in the form of sections not over 45 X 45 m each, separated from each other by keyed expansion joints.

It is recommended that the sections of the shoring be planned in the form of individual sections with dimensions of 5 X 5 m and over.

The length of the sections and the dimensions of the slabs may be increased with the proper justification. The reinforcement should be continuous within each section.

2.30. The shoring of slopes made of precast reinforced concrete slabs may be stipulated with monolithized individual slabs in a peat drainage channel after the slab is placed on the slope, and with the appropriate justification--they may be made from nonmonolithized slabs with open joints.

The maximum size of the slabs should be established on the basis of the conditions for transporting and the convenience of placing the slabs on the slope.

Some slabs in peat drainage channels should be joined to each other by welding the outlets of the working reinforcement before monolithizing.

2.31. The thickness of the monolithic and precast reinforced concrete shorings should be determined by calculation in accordance with the requirements of the normative documents for planning hydraulic engineering structures exposed to waves, and according to the results of special studies.

2.32. When the dams have shallow slopes and the height of the wave is not over 1 m, light shoring in the form of a layer of coarse rubble soil, with the coarseness of the particles and the thickness to be determined by calculation, may be used.

2.33. The shoring of the downstream slope should be stipulated if it must be protected from atmospheric actions and destruction by burrowing animals.

2.34. To be stipulated for the shoring of the downstream slope are turfing (solid or in a square), a planting of grass along the layer of vegetal land, 0.2-0.3 m thick, pouring rubble or gravel in a layer 0.2 m thick and other types of light coverings.

2.35. If the downstream slope is exposed to ice and waves from the tail-water side, its shoring should be stipulated similar to that for the upstream slope, taking into consideration the drainage devices and overload stipulated by the plan.

2.36. The preparation for the shoring of the slopes (which in many cases is a reverse filter) is made in the form of a rock fill, slabs with open joints or with through holes, etc., and may consist of a layer of material varying in the size of the granules or two or three layers of material with particles of varying coarseness.

2.37. The selection of the material for the preparation, the number of layers and their thickness is made in relation to the type of soil of the slope, the presence and composition of local material, on the basis of the results of a technical and economic comparison of the variants.

2.38. A sandy overburden, the granular composition and thickness of which is established on the basis of the data from calculations and studies, should be stipulated for the preparation of the shorings on slopes made of clayey and fine sandy (or thinned out with dynamic loads) soil.

2.39. A single-layer preparation should as a rule be stipulated for shoring made of monolithic or precast reinforced concrete slabs (with compacted joints or monolithized in plots) on slopes made of sandy or clayey soils.

Note. With appropriate justification the preparation for the monolithic slabs may not be stipulated. In this case a reliable structure must be ensured for joints which prevent the erosion of the soils of the slope.

Impervious Devices

2.40. Impervious devices are designed to reduce the seepage flow, to prevent dangerous seepage deformations of the soil of the dam and its foundation and to increase the stability of the downstream slope.

Impervious devices should be designed from almost impervious soils (clay-gravel mix, clayey and fine sand) and from turf or non-earth materials (concrete, reinforced concrete, polymeric or bituminous materials, etc.), in the form of a facing, core, diaphragm, blanket, cutoffs, sheet pile, pile-column and trench cutoff walls, grout and other curtains.

Notes: 1. Mixtures of soils (clayey with coarse rubble or sandy soils) and gravelly soils with a non-piping composition and a seepage coefficient of $k_f < A \cdot 10^{-3}$ cm/sec may be stipulated for impervious devices (cores, facings, blankets).

2. Turf may be used in facings and blankets of dams only with the proper justification when the degree of decomposition of the plant residues is at least 50%.

2.41. The types of impervious devices should be selected in relation to the type of earth dam, the nature of the soils of the embankment of the dam and the foundation, the presence at the site of the necessary soils or non-earth materials for the impervious devices, the height of the dam, the position of the confining stratum of the foundation and the work conditions on the basis of the results of a scientific and economic comparison of the variants.

2.42. Impervious devices in the embankment of the dam should be firmly connected to the impervious devices in the foundation of the dam, and if there are no impervious devices in the foundation--to the foundation itself.

It is recommended that the core, diaphragm or face of the dam be joined to its foundation by cutting them into the foundation or joining them with the upper part of the sheet piling driven into the foundation, as well as by installing grout curtains (see Figs. 1 and 2).

2.43. The thickness of the soil facing or core of the dam should increase from top to bottom.

The minimal size of the facing or core along the top is designated in accordance with the work conditions, but is at least 0.8 m, and below--is based on the fact that the gradients of the filtered flow adopted for the gravel-clay, clay and loamy clay are not over $I=10$ (and only with the appropriate justification $I=12$), and not less than $I=4$.

The parts of the core or facing, as well as the blanket, which might be frozen and eroded as the result of considerable water rates (for example, at the approach to the bottom outlet conduit) should be covered with an appropriate protective layer.

The crest of the earth facing (after the final settling of the dam) should be no lower than the augmented level of the water in the headwater, taking into consideration the height of the wave and the surge of the water level (see section 2.12).

The displacement resistance of the protective layer along the facing, as well as the protective layer combined with the facing along the soil of the embankment of the dam should be checked by calculation in accordance with the requirements of part 5 of this chapter.

2.44. When the confining stratum occurs at a depth, a blanket or curtain should be installed at the facing, and at the core--a curtain. The blanket is a continuation of the facing and may be made of the same material as the facing.

The length of the blanket should be designated in relation to the permissible seepage rates, as well as in accordance with the specification of preventing dangerous seepage deformations of the soil of the foundation of the dam with the emergence of the flow into the tailwater.

The thickness of the blanket should be adopted on the basis of the fact that the gradients of the seepage flow arising in the blanket should be not over $I=10\div12$. The least structural thickness of the blanket should customarily be not less than 0.5 m.

Note. If the upstream shell of the dam is formed with coarse soil, provision should be made for transitional layers of soil placed according to the principle of the reverse filter (the same is true when designing the blanket).

2.45. The axis of the cross section of the core should as a rule be vertical; this axis should coincide with the axis of the cross section of the dam.

2.46. When there are no clayey soils suitable for the construction of a filled core at the construction site of the dam, there must be provision for a grout core for the dam, by forcing a special packing material of varying composition and consistency into the porous space of the soil of the dam embankment.

Recommended for use for this material are: with the average coefficient of soil seepage $k_g > 0.1$ cm/sec, a clay-cement mortar containing at least 20% by weight; with $k_g < 0.1$ cm/sec, a clay-silicate mortar, aluminate-silicate mortar, clay-polymer or polymer mortars based on various resins, for example, acrylamides, etc.

The grout core on the bottom should customarily have a thickness of not less than $1/10$ of the pressure head on the dam.

The grout core should have the necessary seepage strength, ensuring its durability.

Note. The grout core makes it possible to build the dam without preparing the foundation, with construction without cofferdams and a year-round operation cycle, as well as under severe climatic conditions. In this case the proper supervision of the monolithic core must be ensured.

2.47. Bituminous concrete facings should be made of hydraulic engineering bituminous concrete, the assigned physical and mechanical properties of which are established by the necessary studies. Particularly, the composition of the bituminous concrete and the grade of the binding agent (bitumen) should be selected so as to eliminate the possibility of the dusting of the facing under any possible temperature conditions.

The thickness of the bituminous concrete facing is designated on the basis of the specifications for its strength on the basis of calculations which take into account the structural and mechanical properties of the bituminous concrete.

2.48. When polymeric materials are used as a facing (for example, polyethylene films, etc.), the film should be guaranteed protection against mechanical actions, solar radiation, etc. The films are selected so as to ensure the possibility of deformation of the supporting prisms without disturbing their unimpaired condition. Films made of stabilized polyethylene should be used for the facings of dams.

Polyethylene facings are made by joining (welding, cementing, etc.) sections of polyethylene film. The maximal coarseness of the sandy fractions underlying the polyethylene film (thickness 0.3-0.5 m) and covering it (thickness at least 0.5 m) should be not more than 6 mm.

The soil of these layers should as a rule undergo special processing, eliminating damage to the film by rodents and plants.

Polyethylene facings may be used for dams of classes III and IV, as well as for more critical dams up to 60 m high, with the proper justification.

2.49. Concrete and reinforced concrete (precast and monolithic) diaphragms should be stipulated to be made from concrete of the planned grade for a crushing strength no lower than 200 and a grade of concrete not lower than V8 with respect to the impervious quality. Diaphragms should be cut by lateral vertical and, along the height, horizontal joints with the appropriate packing, taking into consideration the possible temperature and settling deformations.

2.50. Bituminous concrete diaphragms should be designed to be made of poured, plastic or compacted, fine-grained bituminous concrete. The composition of the bituminous concrete should be selected individually, taking into consideration the special features of the work of the diaphragm during the construction and operational periods.

Bituminous concrete diaphragms should as a rule be stipulated:

When there is no clayey soil at the construction site;

When high deformations are anticipated for the embankment of the dam (roughly over 1.5-3% of the height of the dam);

For regions with increased seismicity (over 8 points);

For regions included in the Northern construction-climate zone.

To be stipulated for transitional layers adjacent to the diaphragm are soils with the maximal size of the pores not over 0.5-0.6 of the size of the largest fractions of the bituminous concrete filler.

For economic reasons and on the basis of specifications for the increased reliability of the work of the diaphragm made of poured bituminous concrete, it is expedient to stipulate that assorted rock be embedded in the body of the diaphragm in an amount of 30-40% of its volume. The maximal size of the rocks should not be over 0.3 of the estimated thickness of the diaphragm.

The dimensions of bituminous concrete diaphragms should be designated by calculation on the basis of the physical and mechanical properties of the compositions of bituminous concrete used, the estimated temperatures of the air and the anticipated deformations of the embankment of the dam in the construction period and the operational period. The thickness of the bituminous concrete diaphragms should customarily be 0.02-0.03 of the magnitude of the effective pressure head, but not less than 0.4-0.6 m.

2.51. Polyethylene diaphragms (vertical or sloping) should be planned with guidance from the requirements of section 2.48.

Drainage Devices

2.52. Drainage should be stipulated for the embankment of an earth dam for the purpose of:

- a) Preventing seepage flow from emerging on to the downstream slope and into the zone exposed to freezing;**
- b) An economically justified reduction in the depression curve to increase the stability of the downstream slope;**
- c) Runoff of the water seeping through the embankment and foundation of the dam, into the tailwater;**
- d) Preventing the occurrence of seepage deformations.**

Notes: 1. The water seeping through the facing, core or diaphragm should be removed by a separate horizontal drainage layer connected to the drain of the downstream shell of the dam.

2. The installation of horizontal or vertical drains in the mass of the downstream shell and central part of the embankment of the dam may be stipulated in high dams made of clayey or sandy-loamy soil in order to accelerate the consolidation and eliminate the effect of pore pressure.

2.53. Drainage devices for the downstream shell of the dam are divided into the following types with respect to their design (Fig. 3):

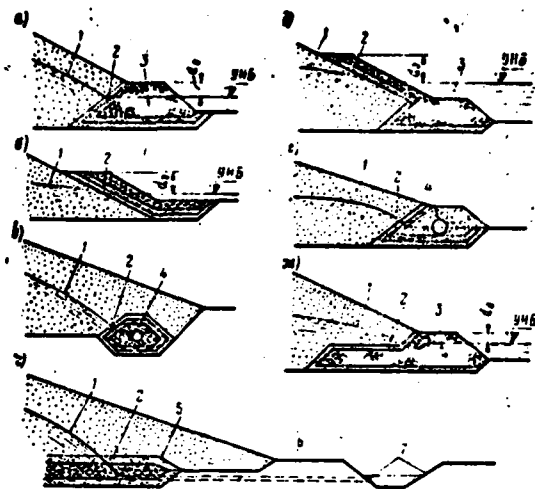


Figure 3. Diagrams of the Principal Types of Drainage

a--drainage banquette; b--sloping drain; c--pipe drain; d--horizontal drain; e, f, g--combined types of drainage; 1--depression curve; 2--reverse filter; 3--banquette; 4--pipe; 5--drainage belt; 6--outlet pipe; 7--runoff gutter

- a) Drainage banquette;
- b) Sloping drain;
- c) Pipe drain (vertical or horizontal);
- d) Horizontal drain (in the form of a continuous layer or drainage "belt");
- e) Combined drainage.

Drain design includes a reverse filter and a drainage collector. The reverse filter should be specified as being made of sand, gravel or rubble, as well as from porous materials (porous concrete, etc.). The drainage collector should be designed of stone, concrete, reinforced concrete, bituminous concrete, ceramic pipes, etc.

2.54. A drainage banquette (Fig. 3,a) should as a rule be made in the channel sections of a dam when it is built without cofferdams and when the river is spanned with stones poured in the water.

The rise of the crest of the drainage banquette, d_0 (if there is no sloping drain) above the level of the tailwater should be determined by the position

of the maximal water level, in the tailwater with a reserve for wave action, the magnitude of which is determined in accordance with section 2.12, but not less than 0.5 m. The width of the banquette on top is designated in accordance with the work conditions, but is not less than 1 m.

When the embankment of the dam and the drainage banquette are joined, the seepage strength where the soil of the dam joins the soil of the banquette should be ensured by installation, when necessary, of a reverse filter along the inner slope of the banquette.

A horizontal reverse filter should be stipulated if there is fine soil in the foundation and there are high outlet rates of seepage under the drainage banquette. It is recommended that the crest of the drainage banquette be covered with a layer of coarse rubble soil.

2.55. It is recommended that a sloping drain (Fig. 3, b) be made in the sections of the dam which span an inundated flood plain, and when there is not a sufficient quantity of rock at the site.

The thickness of the sloping drain, t , should be designated according to the conditions for the work, but be not less than

(3)

where D_m is the diameter of the rock used in accordance with 2.26;

$S_{\text{obp. } \phi}$ is the thickness of the reverse filter.

The elevation of the crest of the sloping drain, d_0 (Fig. 3, b and e) above the maximal level of the tailwater should be adopted, as for the drainage banquette (section 2.54), in consideration of the height of the wedging out of the seepage flow to the downstream slope of the dam.

2.56. A pipe drain (Fig. 3, c) should be used only at the sections of the dam where there is no water in the tailwater during its operation.

The pipe drain should be stipulated as being made of concrete or bituminous concrete pipes (perforated) with sealed or unsealed joints, with a cushioning (when necessary) corresponding reverse filter.

The cross section of the drain pipes should be determined by hydraulic calculations based on the conditions for ensuring free movement of the water in the pipes.

Inspection pits must be stipulated every 50-200 m along the length of the pipe drain.

2.57. The horizontal drain (Fig. 3, d) should be designed in the form of a continuous (flat) drainage layer or in the form of individual horizontal lateral or longitudinal drainage belts made of coarse material and protected by a reverse filter.

2.58. Combined drainage (see Fig. 3, e, f, g) is one of the possible combinations of the drains mentioned in sections 2.54-2.57. The elevation of the crest of the banquette of a combined drain (see Fig. 3, e) should be designated on the basis of the conditions for spanning the river bed.

2.59. The dimensions of drainage devices in the form of flat drains, drainage belts or pipes should be determined by hydraulic and seepage calculations and are adopted in consideration of the conditions for making the drain.

2.60. The type of drainage devices may vary at different sections of the dam, and its design should be selected on the basis of the data from technical and economic comparison of the variants, depending on:

- a) The type of dams, and the geological engineering and hydrogeological conditions at the foundation and the banks;
- b) The physical and mechanical characteristics of the soils for the drain and their quality;
- c) The work conditions (taking into consideration the degree of prefabrication of the drainage devices);
- d) The climatic conditions of the construction region;
- e) The operating conditions of the structure.

2.61. The drainage device for the embankment of the dam need not be specified with the appropriate justification in the following cases:

- a) When the dam is being built on a pervious foundation and there is a low level of stand of the ground waters, at which the depression curve without a drainage device proves to be sufficiently removed from the surface of the downstream slope and does not go beyond the limit of the seasonal freezing;
- b) In the downstream section of dams with facings, cores and diaphragms, on condition that the removal of the seeped water is ensured;
- c) In dams, the downstream shell of which is made of rockfill or of other coarse material (gravel, shingle, etc.).

2.62. When the earthfill dam is joined to a concrete one placed on a non-rocky foundation, the drainage of these dams should be connected.

2.63. At the sections of the dam on the side of the tailwater, where the surface of the earth is above its level, organized removal of the water seeping through the dam should be specified (for example, horizontal drainage).

2.64. When earthfill dams are constructed on watersaturated soils in which, under the load from the dams high excess pore pressure may occur and disturb

the strength of the foundation and cannot be reduced by reducing the intensity of erecting the dam, the entire surface of the foundation within the downstream shell of the dams or part of it must be covered by horizontal drainage. To facilitate the removal of the water forced out of the soil of the foundation, it is recommended that in addition, vertical sand drains be installed in the form of drill holes filled with sand. The need for such drainage and the distance between the drill holes should be substantiated by calculation of the consolidation of the foundation, taking into consideration the intensiveness of the dam erection.

2.65. If the upper layer of the soil of the foundation is almost impervious as compared with the underlying soil, the stability of its upper layer (in the tailwater area) should be evaluated by calculation for the heaving of the upper layer of soil due to the rising seepage flow. If the stability of this layer is insufficient, a vertical drain, cutting through this layer and reducing the counter pressure, should be constructed at the downstream toe of the dam.

Note. With the appropriate justification, instead of the vertical drain, an overburden of the surface of the earth behind the downstream slope of the dam may be specified.

Reverse Filters

2.66. Reverse filters should be stipulated at the contact of the drain (or overburden) and the drained embankment of the dam (or core, facing) or the foundation of the dam.

The materials of the reverse filter should be selected on the basis of the conditions for preventing the disturbance of the seepage strength of the contact of the adjacent soils in the process of building, and during the operation of the dam, and also on the basis of the recommendations of the appropriate normative documents.

Note. It is permissible not to specify the installation of a reverse filter only with special justification, and in this case it should be borne in mind that installing this filter along the contact with the drain is not obligatory if the drained embankment is formed with gravelly sand, gravelly soil, etc.

2.67. The granular composition of the material of the reverse filter should be selected in consideration of the nature of the soil being drained and the available local filter materials.

The composition of the filter should eliminate:

- a) Separation of the clayey soil at the contact with the filter material--for dams made of clayey soil or dams on a clay foundation;
- b) Penetration of the particles of the protected soil in the pores of the filter for zones of descending seepage flow in dams made of sandy soil;

c) Heaving of the soil into the pores of the filter material for a sand foundation in the zone of ascending flow;

d) Erosion of the protected soil at the boundary with the filter if the seepage flow is directed along the contact.

2.68. The number of layers of reverse filter and their composition should be determined on the basis of the appropriate technical and economic substantiations; here an attempt should be made to designate the smallest possible number of layers of reverse filter.

2.69. The selection of the material of the reverse filter of the drainage for dams of classes I and II should be checked experimentally for soils and under work conditions for the structure, and for dams of classes III and IV--in consideration of section 2.67.

2.70. The thickness of the layers of the reverse filter should be determined on the basis of the work conditions, but be not less than 0.2 m when the filter is placed near the drain pipe and when the filter layers are sprinkled dry in the drainage devices.

2.71. The materials for the reverse filters of a vertical pipe drain for the foundation should be stipulated in accordance with the requirements of the normative documents for drilling wells in water.

2.72. The rock, gravel and rubble used for reverse filters for drainage in zones of possible freezing should be frost resistant, should not become soft and not dissolve when exposed to the seepage water, the water of the reservoir and of the tailwater.

Joining the Embankment of the Dam to the Foundation, Banks and Concrete Structures

2.73. To prevent dangerous contact seepage between the base of an earth dam and its foundation, measures should be stipulated in relation to the nature and state of the soils of the foundation and ensuring a tight joining of the soil of the embankment of the dam to the soil of the foundation.

In the plans for dams erected on a non-rocky foundation, measures should be stipulated to prepare (within the limits of the dam) the foundation, including those for felling the timber and undergrowth, uprooting the stumps, removing the vegetative layer and the layer pierced by the rootstock of trees and bushes or the routes of burrowing animals, as well as for removing the layer containing a considerable amount of organic inclusions or salts easily soluble in water (see section 2.3), or if expedient, for constructing a cutoff in the foundation of the dam.

When designing earth dams erected on a rocky foundation, the removal of the broken rock should be stipulated, as well as the removal of individual large rocks and rock piles on the entire area where the water confining elements of the dam join with the foundation, and the closing up of the holes from geological prospecting and construction.

It is not obligatory to remove the broken rock at the sections where the foundation joins the parts of the dam structure which are made of materials more pervious than the impervious devices.

When the foundation has a surface layer of soil with lower strength (shift) characteristics than the soil of the dam, the economic expediency of removing this layer (or the upper part of it) must be ascertained, taking into consideration the fact that with such a removal of the soil of the foundation the slopes of the dam may be designated as steeper.

Note. Constructing dams in seismic regions on foundations made of soils capable of being thinned through dynamic actions should be avoided.

2.74. The sloping surfaces of non-rocky and rocky banks within the limits of the section adjoining the dam should be planned accordingly; benched sections should be avoided, and overhanging sections are not permitted within the foundation of the impervious devices of the dam.

If there is rapidly eroding rock in the foundation of the dam, provision must be made to cover the foundation, after it is cleared off, with a layer of the soil of the embankment of the dam (or other measures taken to prevent erosion).

If a rocky foundation has local large tectonic damage in the form of separate wide and deep cracks, the appropriate measures must be taken to clear them and fill them up, as well as to increase the seepage strength of the material fillin up these cracks.

2.75. If the foundation has muddy and overmoistened clayey soils in which pore pressure may appear, with the related reduction in the soil's resistance to displacement, provision must be made to drain the foundation and to establish the degree of intensiveness of erecting the dam.

2.76. For earth dams with impervious devices and homogeneous earth dams made of clayey soils, planned on strongly filtering alluvial deposits which cover the fissured rock of the foundation, with a relatively thin alluvial deposit (up to 5 m), provision should usually be made to continue the impervious devices up to the rock to join them with the rock by putting in a cutoff.

When the alluvial layer is relatively thick (over 5 m), in each individual case a comparison should be made of the variants of the dams with a core and impervious barrier (grout curtain, concrete wall, etc.) and the dams with a facing and a blanket.

The plan should stipulate measures ensuring a secure juncture of the impervious devices of the dam with the foundation where the cut-off adjoins the rock (for example, by grouting the foundation at the join, and if necessary, installing an impervious curtain). The depth of the suspended impervious barrier and the length of the blanket should be determined on the basis of the given seepage calculations.

Note. When making the seepage calculations, the silting of the bed of the reservoir and the upstream slope of the dam may be calculated, based on its manifestation in time.

2.77. If the impervious elements of the dam and the sloping irregular surfaces of the rocky banks join, these surfaces should be evened off with concrete.

The slope of some sections of the surface of the bank, where they join the impervious elements should vary with angles of not over 10° .

2.78. In earth dams on fissured rock foundations, along which seepage, dangerous for the embankment of the dam, may take place, provision should be made for installation of a cutoff and an impervious curtain under it, as well as arranging surface reinforcing grouting within the base of the impervious structure of the embankment of the dam. It is not recommended that in these cases homogeneous dams without impervious devices be planned.

2.79. When earth dams are planned on impervious and uncracked rock, semi-rock and clayey foundations, it may be stipulated that the embankment of the dam be placed directly on the foundation, without making impervious devices in it.

2.80. Where the embankment of the dam joins its foundation, the banks and concrete structures, stipulation must be made of very careful placing and compacting of the soil of the embankment of the dam near the surface of the juncture, for which the first layer of fill must be placed from soil with an increased (by 1-3%) moisture content.

2.81. When a watertight barrier is installed in the foundation (metal piling, a solid wall made of concrete or clayey soil, a "drilling" wall made of concrete or clay-cement, a grout curtain, etc.), it must be specified that it join directly with the impervious elements of the dam (core, facing or diaphragm).

Note. The depth of the impervious curtain and the area grouting may be reduced in the process of the work with the appropriate technical and economic justifications.

2.82. The devices of earth dams which adjoin concrete and reinforced concrete structures should ensure:

- a) Protection of the earth dam against its erosion by water passed through the spillways;
- b) Continuous access of the water to the intakes and spillways from the headwater and continuous flow into the tailwater, preventing erosion of the embankment and foundation of the dam;
- c) Prevention of dangerous seepage in the juncture zone.

Note. Plans for the adjoining devices of dams of classes I, II and III should be substantiated with the data from laboratory hydraulic and seepage research.

2.83. To ensure the best juncture of the embankment of an earth dam and a concrete structure, stipulation should as a rule be made of a vertical gradient of the adjoining edges of the concrete structure (with the exception of diaphragms) of not over 10:1.

The joining of an earth dam and concrete structures should be packed particularly carefully.

The juncture of an earth dam with concrete structures cutting across its embankment should be made for dams with impervious devices in the area of these devices, and for homogeneous dams within the limits of the upstream shell and the central part of the dam.

The juncture of the embankment of an earth dam and concrete structures should be stipulated in the form of diaphragms built into them, cutting into the earth dam (piling, concrete wall, etc.). The length of the diaphragms of the juncture should be determined on the basis of data from seepage calculations.

Note. Impervious devices in the foundation of earth dams and concrete structures should be interconnected.

3. HYDRAULIC EARTHFILL DAMS

3.1. Hydraulic fill dams, depending on the material of the embankment of the dam and the methods of erecting them, should be divided into the following basic types (Table 4).

3.2. The design of the dams should be selected in accordance with the instructions in section 1.5, and an attempt should be made toward maximal utilization of the natural run-of-bank mixtures.

3.3. If there are no run-of-bank soils suitable for nonhomogeneous dams, homogeneous dams up to 50 m in height with a compulsory shaped slope may be built.

3.4. Nonhomogeneous dams should as a rule be specified if there are appropriate run-of-bank soils and if the seepage rate of the water should be reduced.

3.5. Dams with freely formed slopes are permitted up to 10-15 m in height if there are loose soils in the foundation or if it is necessary to do away with reinforcing the slopes and easing them.

3.6. Homogeneous and nonhomogeneous hydraulic fill dams with side rockfill prisms (see Fig. 4, d,e) may be specified on condition that high cofferdams

Table 4. Types of Hydraulic Fill Dams

Types of dams	Materials of dam embankments	Method of erecting dams (Fig. 5)
1. Homogeneous (dams without a core) (Fig. 4, a,b)	a) Sandy soils with a coefficient of grain-size variation not over 5 b) Sandy-loam soils c) Loamy (loess) soils	Cross section of dam shaped compulsorily (installation of protective bank) or as result of free flow of pulp (from one or both slopes)
2. Nonhomogeneous (dams with a core or fine sand central zone (Fig. 4, c, d, e, f)	a) Gravel (rubble) and sandy with core made of clayey, sandy-loam or fine sand soil b) Sandy soils with central fine sand zone	Cross section shaped compulsorily, fill made from both sides with maintenance of pond

or the rock from useful excavations be used. When planning dams for seismic regions it is recommended that rockfill prisms and an overburden of the slopes be made (see Fig. 4, f).

Note. Hydraulic fill dams with impervious devices in the form of diaphragms, facings, blankets, etc. may be specified with the proper substantiation.

3.7. The plans for hydraulic fill dams should stipulate measures to ensure the quality of the earth fill and the required density of its placement in the embankment of the dam, and a solution must be found to the problems of the stability of the slopes, particularly with exposure to water filtered with the fill.

Requirements for Materials

3.8. The granular composition of run-of-bank soils should be regarded as the principal characteristic in evaluating the technical possibility of erecting hydraulic fill dams and the economic expediency of the design chosen.

Note. A content of organic and water-soluble impurities in the soils for the hydraulic fill of a dam is permitted in amounts at which their residue in the embankment of the hydraulic fill dam, after the fill work, is not greater than the values given in section 2.3.

3.9. The preliminary evaluation of the suitability of the run-of-bank soil for the fill of dams of various designs, depending on the content (in percents) of particles of a certain size in the given soil should be made in accordance with Figure 6. Preferred for the fill of homogeneous dams are the sandy soils of group I; sandy and gravelly soils of group II should be specified for nonhomogeneous dams with a fine sand core or fine sand central

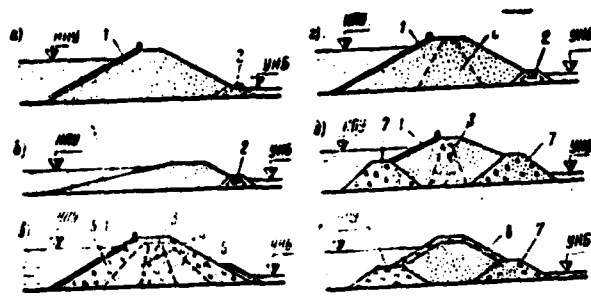


Figure 4. Types of Hydraulic Fill Dams

a and b--homogeneous; c and d--nonhomogeneous; e and f--homogeneous (or nonhomogeneous) with partial fill section; 1--shoring of upstream slope; 2--drainage banquette; 3--core; 4--intermediate zone; 5--side zone; 6--central fine sand zone; 7--rockfill prism; 8--gravel and shingle or rock overburden

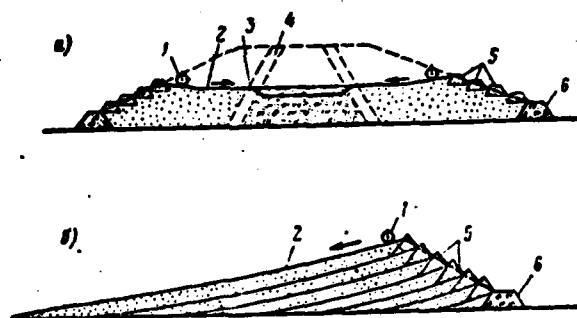


Figure 5. Principal Diagrams for Erection of Hydraulic Fill Dams

a--Two-way fill of nonhomogeneous dam with core; b--one-way fill of homogeneous dam with upstream slope formed through free flow of pulp; 1--distributing pulp line; 2--slope of fill; 3--edge of settling pond; 4--edge of core; 5--levee of parallel protective bank; 6--levee of primary protective bank

sons. Sandy loams (group III), loams (group IV) and gravel and shingle soils (group V) may be stipulated for the fill of dams with the appropriate technical and economic substantiation. In this case the sandy loams and loams (loess-type soils) may be stipulated for the fill of homogeneous dams or the core zone of nonhomogeneous dams, loams and clays--for the core of dams, and gravelly soils--for the supporting prism.

Note. The soil reserve in the quarry should be 50-80% greater than the amount of soil assumed in the plan of the dam.

Рис. 6. Группы грунтов, используемых для насыпи плотин



Figure 6. Groups of Soils Used for Dam Fills

Key:

- A. Content of particles in % by wt.
- B. Diameter of soil particles in mm.

3.10. Of the gravelly sands and gravel (rubble) soils for the fill of homogeneous dams, soils with a maximal degree of variance in granular size are preferred.

The content of clayey particles less than 0.005 mm in size in the core may not be over 20%.

3.11. The possibility of using artificial mixtures of soils from different quarries or assorted quarry soils for the fill, as well as clay with its compulsory dessication, in the embankment of the dam should in each individual case be substantiated by technical and economic calculation.

3.12. To be taken into consideration when selecting sandy soils for the fill of a dam is the fact that the alluvial soils with rounded particles, in the filling, are placed with a greater volume weight and that this soil has a lower coefficient of internal friction than the soil with less rounded particles.

Fractionation of the Soil in the Embankment of the Dam

3.13. Fractionation of the soil in the cross section of the dam resulting from hydraulic spreading should be taken into consideration with the coefficient of the variation in granular size of the fill soil, $k_{\frac{d_{60}}{d_{10}}} > 2.5$ or

$k_{\frac{d_{60}}{d_{10}}} > 5$. In this case the spreading of the soil depends on the variation in granular size of the soil, the width of the beach of the fill, the flow of the pulp and its consistency.

3.14. The washing away and run-off of fine particles of soil must be taken into consideration when planning the granular composition of the soil of

hydraulic fill dams. When erecting sand, homogeneous dams, an attempt should as a rule be made to ensure the dumping of particles less than 0.01 in size and some 0.01-0.05 in size, and with the fill of nonhomogeneous dams this dumping of the clayey particles should customarily take into consideration the requirements of section 3.10.

3.15. When planning homogeneous dams the granular composition of the fill soil should be adopted in accordance with the average composition of the run-of-bank soil, taking into consideration the washing away of the fine particles removed in the filling process, on condition that the homogeneity of its filtration properties is observed for the extent of the fill.

3.16. When planning nonhomogeneous dams the granular composition of the soil in individual parts of it must be determined with regard to the fractionation occurring in the fill. Here the spread of the soil may be determined on the basis of the data from calculation or analogies. When hydraulic fill dams of class I are erected, the spread of the soil should be determined through experimental fill, with maximal adherence to the specification for the industrial process of filling the dam.

Note. The average granular composition of the soil should be determined for the core zone and the side prisms of the dam or for these parts of the dam and in addition for the intermediate zones. Here the breakdown of the dam into zones is adopted in accordance with the available analogies.

3.17. The width of a core made of loamy and sandy loam soil should be designated preliminarily in relation to the composition of the run-of-bank soil within 10-20% of the width of the dam for the given height, and of the central zone made of fine sandy soil--within 20-35% of this width. The size of the core zone should be corrected in accordance with the actual spread of the alluvial soil.

Configuration and Supporting Shoring of the Slopes of Dams

3.18. The gradient of the slopes of hydraulic fill dams and their shoring are designated in accordance with the requirements in sections 2.9-2.39, and the gradients of the slopes should be determined in consideration of the structures and heights of the hydraulic fill dam, the characteristics of the fill soils and the soils of the dam foundation.

First the gradient of the slope may be selected according to analogies of structures constructed from similar soils with the subsequent more precise specification based on calculations and experimental fill of the soils.

3.19. If the upstream or downstream slope of the dam is selected not only in accordance with the results of calculating the stability, but also in accordance with the work conditions and the industrial process adopted for the fill, as well as from considerations of reducing the work for preparing the foundation or installing the shoring, these decisions should be substantiated by data from appropriate technical and economic studies.

3.20. The slopes of hydraulic fill dams formed with a free flow of pulp may be specified without shoring or with light gravel, shingle or biological strengthening under conditions of nondestructive wave and wind action, which should have appropriate substantiation.

3.21. The width of hydraulic fill dams along the crest should be established in accordance with the requirements in section 2.11, taking into consideration the possibility of the work of hydraulic conveyor units and the system adopted to organize the work.

3.22. To be taken into consideration in planning the drainage devices in the embankment of a hydraulic fill dam, in addition to the instructions in sections 2.52-2.72, is the possibility of work being done simultaneously on filling the embankment of the dam and installing the drainage.

3.23. It is recommended that the average values of the gradients of the slopes with free fill of sandy and gravelly soils (for example, with facing, pierless method of fill) be roughly designated (with approximately 10%-consistency of the pulp and its concentrated discharge) according to Table 5, with correction from the results obtained with experimental fill.

3.24. The gradient of the slopes of sandy soils, with underwater fill, depending on the granular composition of the soil and the flow rate, may be designated from 1:10 to 1:4; in this case the lowest value of the gradient is given for a fill of fine sand in the reservoirs, with a flow. With an increase in the coarseness of the soil particles and a reduction in the flow rate and the depth of the reservoir, the gradient of the underwater slope should increase.

Table 5. Average Values of Gradients of Slopes With Free Fill of Sandy and Gravelly Soils

Soil designation	Average gradient of slope with flow rate of pulp, m ³ /hr		
	up to 2000	2000-4000	over 4000
Sand, fine	0.025	0.020	0.010
Sand, average	0.030	0.025	0.015
Sand, coarse	0.035	0.030	0.025
Sand, gravelly	0.055	0.040	0.035
Gravelly soil	0.070	0.055	0.045

3.25. When necessary, measures may be stipulated for a compulsory increase in the density of the sandy soil deposited by its additional compaction (depth hydrovibration, compaction by the method of blasting water-saturated soil, layer vibration compaction or rolling, etc.).

4. EARTH AND ROCKFILL DAMS

4.1. Earth and rockfill dams are subdivided into the following basic types according to the design of the impervious devices (Table 6).

Table 6. Types of Earth and Rockfill Dams

Dams	Types of dams by design of impervious devices
1. Earth (Fig. 7)	a) With earth facing b) With core c) With upstream earth prism d) With central earth prism
2. Rockfill (Fig. 8)	a) With facing made of non-earth materials b) With diaphragm

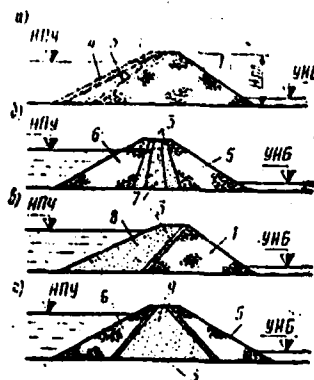


Figure 7. Types of Earth Dams

a--with earth facing; b--with core; c--with upstream earth prism; d--with central earth prism; 1--supporting prism; 2--earth facing; 3--transitional zone (reverse filter); 4--protective layer; 5--downstream prism; 6--upstream prism; 7--core; 8--upstream earth impervious prism; 9--central earth impervious prism; H_d --height of dam

4.2. When planning earth and rockfill dams specification should be made for their erection from a fill of coarse rock using the pioneer method of tiers 10 m high and over or a sprinkling of fine rock by the same method with layers up to 2.5 m thick, at the same time taking the necessary measures to compact them.



Figure 8. Types of Rockfill Dams

a--with facing made of non-earthen materials; b--with diaphragm; 1--supporting prism; 2--subfacing masonry (leveling layer); 3--facing; 4--downstream prism; 5--upstream prism; 6--diaphragm

4.3. Also to be taken into account when planning earth and rockfill dams, along with the general requirements (given in part 1) and the requirements of part 4 are the requirements of part 2, in the section pertaining to the materials for erecting earthfill dams, planning slopes and the crest of dams, impervious devices and their juncture with the foundation, banks and concrete structures.

4.4. Rockfill dams should as a rule be planned on rocky foundations if there are no soils suitable for building the impervious devices. Earth dams may be planned on rocky and, with the proper justification, non-rocky foundations.

Requirements for Materials

4.5. The suitability of the rock for building earthfill and rockfill dams should be substantiated by data from appropriate studies under laboratory and natural conditions.

4.6. With quarry evaluation of the suitability of rock for building dams, the supply of rock, the physical and mechanical properties (specific gravity, volume weight, frost resistance, strength, etc.), the chemical properties (solubility, action on other materials, etc.) and the conditions for processing and transporting the rock should be taken into consideration.

4.7. For dams of classes I and II over 50 m high it is recommended that the laboratory data on the soils be made more precise by studies with experimental fills, (if possible, included in the useful volume of the dam), and for dams over 100 m such studies are obligatory.

4.8. The composition of the rock fill of the embankment of the dam must be planned with regard to the following requirements:

a) Weak, eroded rock is permissible in rock fill only in an amount which does not reduce its strength characteristics and does not increase the deformability of the rock fill;

- b) the coarsest rock should be dumped along the slopes of the dams, which is especially important for dams constructed in seismic regions;
- c) The composition of the rock fill (strewing) should be that which ensures its optimal density;
- d) When the rock is dumped in the embankment of a dam in high tiers, the effect of the segregation of the rocks on the granular composition of the fill along the height must be taken into consideration.

The final composition of the rock fill of earthfill and rockfill dams must be adopted on the basis of technical and economic calculations of the variants of the dams under discussion.

4.9. Unsorted rock should be specified for the fill. Rock sorting may be stipulated only with the appropriate justification.

4.10. The suitability of the rock for the fill (for strength and frost resistance) should be established in relation to the height of the dam, the location of the rock in the section and the climatic conditions of the construction region.

Note. Placing the rock according to the zones of the section of the dam should as a rule be stipulated with a height of the dam of 50 m and over; here the strong rock should be used in the zones under the greatest stress, and rock with inadequate frost resistance--in the interior zones.

4.11. The maximum size of the rock in the fill and its granular composition should be established in the plan in relation to the quality of the rock and the method adopted to construct the dam. The size of the rock dumped in the embankment of a dam with layer-by-layer rolling should be not more than 0.5 of the thickness of the layer dumped.

4.12. For rock designed for placement in the dam below the surface of the water or exposed to its variable action, the coefficient of softening should be no lower than: 0.9 for igneous, metamorphic rock, and 0.8 for sedimentary.

4.13. The use of large substratum rock should as a rule be stipulated for the leveling subfacing masonry of rockfill dams. A preparation made of carefully placed fine rocks or coarse rubble soil may be stipulated for these purposes.

4.14. The same requirements are made of the soils of impervious devices (facings, blankets, cores, cutoffs, impervious prisms) and the transitional zones of earthfill dams as for the soils for hydraulic earth fill dams.

Note. If the impervious device is specified for construction by means of sluicing, the soil must also satisfy the requirements made of soils for hydraulic earthfill dams.

4.15. Run-of-bank soils of varying granular size are as a rule specified for the construction of transitional zones and reverse filters of earth dams.

The possibility of using, for these purposes, dressed soils obtained by sorting, washing, and adding or mixing various fractions is allowed only with the appropriate justification. In all cases preference should be given to the construction of single-layer transitional zones and reverse filters.

The Configuration of the Slopes of Dams

4.16. The basic dimensions of the cross section of earth and rockfill dams should be designated with the requirements of sections 2.9-2.17 as guidelines.

4.17. The width of the berms installed on the slopes should be selected from the conditions for ensuring the required average value of the slope, but be at least 3 m.

4.18. The gradient of the slopes of earth and rockfill dams should be designated by calculation (see sections 5.8-5.11).

Notes: 1. With a rock foundation the average values of the gradients of the slopes of dams made of rock fill, without a facing or other reinforcement, may be taken as:

For the upstream slope, from 1:1.2 to 1:1.3;

For the downstream slope, from 1:1.3 to 1:1.4.

2. If the slope has a facing (soil or bituminous concrete) or other reinforcement, placed on low-strength material covering a slope made of rock fill, the stability of the slope must be determined by the method of circular cylindrical surfaces of displacement and made more precise by additional calculation using the method of flat surfaces of displacement of the facing along the surfaces, suitable for low-strength material.

Impervious Devices

4.19. The guidelines for planning impervious devices made of soil and non-soil materials of earth and rockfill dams should be the appropriate instructions given in sections 2.40-2.51.

4.20. When planning impervious devices for earth and rockfill dams reliable measures should be stipulated to ensure the adaptability of these devices to deformations of the foundation and bank slopes, without at the same time losing the properties of water resistance, strength and flexibility.

4.21. The magnitude of the gradient of the seepage flow for a core or facing made of gravel-clay mix or clayey soil of earth dams should be taken as $I=2-6$.

4.22. Reverse filters and transitional zones preventing the contacts of adjacent soils from destruction during the construction and operation of the structure should be stipulated between the earthen impervious elements of the dam and the supporting prisms. The thickness of the layers of the transitional zones should be designated from the work conditions, taking into consideration possible horizontal displacements of the dam, and is customarily not less than 3 m.

4.23. The materials of the layers of the transitional zones and reverse filters for dams of all classes should be planned in accordance with the requirements of part 5 and other normative documents.

The granular composition of the transitional zones for dams of classes I and II should be precisely defined by experiment, taking into consideration the work conditions.

4.24. High dams situated in a narrow river bed should be designed with a curved configuration in the plan with the convexity on the tailwater side to avoid cracks appearing in the facing or core of the dam.

4.25. To increase the strength of earthen impervious devices for earth dams, with technical and economic substantiation stipulation may be made of:

- a) Thickening of the core or facing at the bank abutments and in the foundation;
- b) Placing an additional layer of reverse filter (placed along the perimeter) only within the limits of the juncture of the earthen core or facing with the foundation and banks;
- c) Constructing a facing or core made of clayey soils of varying granular composition, capable of being silted (self-welding) if cracks form in them.

4.26. Impervious devices of rockfill dams may as a rule be designed from reinforced concrete, bituminous concrete, polymers and wood.

4.27. Reinforced concrete facings, depending on the height of the dam and the anticipated settling, may be of two types: semi-rigid (single-layer) and flexible (multi-layer). Flexible designs of reinforced concrete facings should as a rule be stipulated for high dams.

4.28. Single-layer reinforced concrete facings consist of individual slabs, between which vertical expansion and horizontal keyed expansion, watertight, sealed joints are made. The cutting of the facing into individual slabs should be stipulated with consideration of the configuration of the bank slopes.

4.29. Concrete for reinforced concrete facings should have a planned grade for crushing strength not lower than 200 and the grades of concrete for watertightness should be not lower than V8. The planned grades of concrete

with respect to frost resistance and imperviousness should be designated in accordance with the requirements of the state standard for hydraulic engineering concrete. The thickness of the slabs of the reinforced concrete facing and their reinforcement should be determined in accordance with the estimate of the stability of the slab on the slope, the wave and installation load strength and in consideration of the deformation of the slope of the dam.

4.30. Flexible reinforced concrete facings should be specified to be made from several rows of slabs with layers of waterproofing placed between them. The slabs of the facing should (except for the upper layer), without being interconnected in the rows, be placed with a clearance and bonding of the joints.

4.31. The dimensions of the slabs should be chosen so that the facing is ensured sufficient flexibility on the whole, with a relatively small number of joints.

The dimensions of slabs concreted at the site may be accepted within limits of 10 to 20 m (side of the square).

4.32. To ensure the connection between the separate rows of slabs and the facing as a whole and the embankment of the dam, anchor bolts or other structural measures should be stipulated to prevent the slabs from creeping along the slope. It is not permissible to place the slabs and the facing as a whole on a flat surface without anchoring.

4.33. The juncture of non-earthen facings and the foundation of the dam should be specified by means of a concrete cutoff, in which, for high dams, a drainage gallery may be installed, serving simultaneously to create a grout curtain in the foundation.

4.34. The connection of the facing and the cutoff may be specified in the form of a semi-rigid (split) or flexible structure (layered, with the facing embedded in the cut-off, hinged with the installation of a flexible joint along the perimeter). For high dams the flexible connection of the facing and the cut-off is obligatory.

4.35. Compensation devices (expansion joints) should be specified along and across the facing to reduce the temperature and settling stresses.

Anchor bolts embedded in the subfacing masonry should be stipulated to prevent the facing from separating from the embankment of the dam. When the slope is long and there are considerable fluctuations in the water level in the reservoir, horizontal expansion joints should also be specified, as a rule made in the section of the dam within the limits of a sharp change in the cross section of the gorge.

4.36. Wooden facings may be planned, given favorable conditions, ensuring the long state of preservation of the wood and the possibility of repairing the facing when the dam is being operated.

4.37. Bituminous concrete facings may be specified primarily in regions with a temperate continental climate (absolute minimum of the temperature is -45°). The use of these facings requires special justification.

4.38. A subfacing preparation or stone masonry (concrete blocks) placed dry should be installed beneath facings made of non-earthen materials.

4.39. The subfacing masonry should be specified to be made from substratum rock in rows horizontal or perpendicular to the slope, with careful wedging.

The thickness of the subfacing masonry should be designated in relation to the materials of the facing, the steepness of the slope, the anticipated settling of the rockfill dam, but not less than 1 m on top and within the limits of 0.05-0.08 of the height of the dam below.

4.40. The placing of the subfacing preparation made of compacted coarse rubble soil or fine rock should be stipulated by the rock fill.

The thickness of the subfacing preparation made of coarse rubble soils should be designated in relation to the material of the facing, the size of the material of the subfacing preparation, the size of the rock in the fill, the height of the dam and the conditions for the work.

Requirements for the Foundations of Dams and the Juncture of Dams With the Foundation.

4.41. In evaluating the soils of the foundation, it should be taken into consideration that the quality of the foundation determines the type and structure of the dam, as well as the method for the work done to erect it.

The requirements given in sections 1.6-1.8 and 2.73-2.83 must be taken into consideration in evaluating the foundation.

4.42. The possibility of leaving weak soils with poor friction, cohesion and pervious qualities in the foundation should be determined on the basis of a technical and economic analysis.

4.43. When constructing dams on rocky and especially on non-rocky foundations, the amount of unevenness of the settling of the foundation must be determined by calculation both crosswise and lengthwise to establish the impossibility of cracks arising in the impervious elements of the dams.

4.44. When planning earth dams with earthen impervious devices, erected by the method of dumping soil in the water, secure contact of the soils of these devices with the soil of the foundation should be stipulated.

4.45. Where the facing or core of the dam joins the foundation and the banks there should be specification of very careful placement and compaction of the soil in the contact zone of the impervious devices, using for this purpose soil which is more plastic and more piping resistant and has the capacity of silting up cracks in the rock foundation.

4.46. The juncture of the earthen impervious devices of the embankment of the dam and the rock foundation may be stipulated to be in the form of guniting the foundation and the bank slopes.

5. BASIC CONDITIONS FOR DAM ESTIMATES

5.1. When planning dams of classes I and II made of earthen materials the following basic estimates should be made:

- a) Seepage (sections 5.3-5.5);
- b) Seepage strength (section 5.6);
- c) Reverse filters, drains and transitional zones (sections 5.7);
- d) Stability of the slopes, facing and protective layer (sections 5.8-5.11);
- e) Settling of the embankment of the dams and foundation and horizontal displacements (sections 5.12-5.17).

To be made in addition are:

For earthfill dams with a core--estimates of the fractionation of the soil and the stability of the side prisms of the dam (sections 3.13-3.25 and 5.19);

For earthfill and rockfill dams which have the embankment, core, facing or foundation formed from clayey soils--estimates of the pore pressure with their consolidation and testing of their crack-resistance (sections 5.20-5.24);

For earthfill and rockfill dams--estimates of the stressed state of parts of the embankment of the dams, and for earthfill dams, in addition, testing of the resistance to displacement of the downstream wedge of the dam (sections 5.25 and 5.26).

For dams of classes III and IV the estimates should be restricted to those given in paragraphs "a," "b," "c," "d" and "e."

The estimates should be made for the most characteristic cross sections of the dams.

5.2. The estimates of dams in all cases should be made for the basic and special combinations of loads, in the operating period of the dams and the period of their construction.

5.3. Seepage estimates of the embankment of the dams, the foundation and the banks should be made to determine the principal parameters of the seepage flow, necessary to:

- a) Estimate the seepage strength of the dam embankment, its foundation and the banks;
- b) Estimate the stability of the slopes of the dam and the banks;
- c) Substantiate the most efficient and economic shapes, dimensions and structures of the dam, and its impervious and drainage devices.

5.4. The seepage calculations (as well as studies) should determine the following parameters of the seepage flow in the embankment of the dam, the foundation and the banks:

- a) The position of the seepage surface of the flow (depression curve) in the embankment of the dam and the banks;
- b) The seepage rate of the water through the embankment of the dam, the foundation and the banks;
- c) The heads (or gradients) of the seepage flow in the embankment of the dam and the foundation, as well as in the places where the seepage flow emerges in the drain, in the tailwater behind the downstream toe, in the places where soils with varied characteristics come into contact and at the edges of the impervious elements.

When the geological structure of the foundation is complex and the structure of the dam is complex, the parameters of the seepage flow mentioned in this item should be determined experimentally, for example by the method of electrohydrodynamic analogy (EGDA).

5.5. The seepage calculations necessary at the preliminary stages of planning dams and their impervious and drainage devices may be made with the study of two-dimensional or spatial problems, using approximate methods of calculation.

5.6. Estimates of the seepage strength of the embankment of dams and their foundations as well as the impervious elements should be made on the basis of the greatest possible pressure head acting on the dam.

The effective average gradients of pressure should be determined by calculation and compared with the permissible ones.

The permissible gradients of the seepage flow of the soils of the foundation and embankment of earth dams, as well as the soil prisms of earthfill dams, should be adopted in accordance with Table 7. For earthen impervious devices (facings, cores and blankets), the permissible gradients of the seepage flow should be adopted according to the instructions of sections 2.43, 2.44 and 4.21.

Table 7. Permissible Average Gradients of Seepage Flow of Soils of the Foundation and Embankment of Earth Dams and the Soil Prisms of Earthfill Dams

Soil designation	Permissible gradients of seepage flow for soils of foundation and embankment of dams of class			
	I	II	III	IV
A. For Soils of Foundations				
Clay, dense	0.90	1.00	1.10	1.20
Loamy clay	0.45	0.50	0.55	0.60
Sand, coarse	0.36	0.40	0.44	0.48
Sand, average	0.30	0.33	0.36	0.40
Sand, fine	0.23	0.25	0.27	0.30
B. For Embankment of Earth Dams and Earth Prisms of Earth Dams				
Clay, dense	1.50	1.65	1.80	1.95
Loamy clay	1.05	1.15	1.25	1.35
Sand, average	0.70	0.80	0.90	1.00
Sandy loam	0.55	0.65	0.75	0.85
Sand, fine	0.45	0.55	0.65	0.75

5.7. Estimates of reverse filters, drains and transitional zones should establish the granular composition, number of layers of natural filter materials or of appropriate artificial mixtures and the thickness of these layers.

When planning reverse filters, drains and transitional zones, the permissible coefficient of the variation in granular size of the filter materials, $k_{\frac{d_{60}}{d_{10}}}$ should satisfy the conditions:

a) If the soil protected is non-piping, free-flowing:

$$k_{\frac{d_{60}}{d_{10}}} < (20 \div 25),$$

where the lowest value of $k_{\frac{d_{60}}{d_{10}}}$ should be adopted for rolled particles of sandy and gravelly soils, and the highest--for rubble soils of the filter;

b) If the soil protected is piping, free-flowing:

$$k_{\frac{d_{60}}{d_{10}}} < 15$$

c) If the soil protected is clayey with the plasticity number $W_p \geq 7$:

$$k_{\frac{d_{60}}{d_{10}}} \leq 50$$

The ratio $k_{\frac{d_{60}}{d_{10}}} \leq 50$ should be adopted for the drains and reverse filters and for the transitional zones of the dams. When the thickness of the transitional zones (reverse filters) of the dams is up to 3 m, this ratio may be adopted regardless of whether the protected soil is clayey or sandy.

When the thickness of the transitional zone of the dams is over 3 m, the value of $k_{\frac{d_{60}}{d_{10}}}$ may be assumed as over 50;

d) For filters made by dumping materials in the water:

$$k_{\frac{d_{60}}{d_{10}}} \leq 10$$

Here

$k_{\frac{d_{60}}{d_{10}}} = d_{60} : d_{10}$, where d_{60} and d_{10} are the dimensions of the fractions of the soil, the weight of which, along with the weight of the finer fractions, constitutes respectively 60 and 10% of the weight of all the soil.

Notes: 1. For filters made of materials with $k_{\frac{d_{60}}{d_{10}}} \leq 10$, the thickness of the layers is designated in accordance with the instructions in section 2.70, and for filters made of materials with $k_{\frac{d_{60}}{d_{10}}} > 10$, the thickness of the layers should be designated in consideration of the segregation of the filter materials occurring with transport, dumping and leveling the layers of the filter, according to the results of experimental dumping.

2. The device of reverse filters or transitional zones for prisms made along a fill of coarse rubble soils may be discarded only with the appropriate justification.

3. Reverse filters made of porous concrete and other porous materials may be stipulated instead of earthen reverse filters, with the proper justification.

5.8. It is recommended that the stability of the slopes of a dam be calculated with the sliding triangle separated into interacting elements by methods which satisfy the conditions of equilibrium of the sliding triangle in the critical state.

Other methods of calculation may be used: the method of horizontal forces of interaction with a circular cylindrical sliding surface; the method of horizontal forces of interaction with a broken line of the sliding surface; the method of inclined forces of interaction with a broken line of the sliding surface; the method of weight pressure with a circular cylindrical sliding surface for the slopes of dams when $m \geq 1.7$ (where $m = c/\gamma a$; see Fig. 1); the method of balance of moments with a circular cylindrical sliding surface for the slopes of the dams when $m \leq 2.5$.

Estimates of the stability of the facing and the protective layer should also be made using the methods of circular cylindrical and two-dimensional shift surfaces.

The safety factor of the stability of the slopes of dams, k_3 , should be not less than the values of the permissible safety factors for the stability of the slopes of dams $k_{3, \text{доп}}$, given in Table 8.

Table 8. Permissible Safety Factors for the Stability of Slopes of Dams, $k_{3, \text{доп}}$

Combination of Loads and Actions	Permissible Safety Factors for the Stability of Slopes, $k_{3, \text{доп}}$ for Dams of Class			
	I	II	III	IV
Basic	1.30- 1.25	1.20- 1.15	1.15- 1.10	1.10- 1.05
Special	1.10- 1.05	1.10- 1.05	1.05	1.05

Notes: 1. The larger values of $k_{3, \text{доп}}$ should be adopted when the elements of the structure of the dam under discussion (slope, facing) or its foundation are formed partially or entirely by clayey or heterogeneous soil.

2. The value of the safety factor for the stability of the facing, the protective layer and the reinforcement of the slope should be similar to those for the slopes of the dam.

3. The values obtained by calculation for the safety factors of the stability with the basic combinations of loads should not be exceeded by over 15%, and for high and superhigh dams--by 30% of their values according to Table 8.

4. In estimates of the stability of the elements of the structure of the dams, the seismic forces and excess pore pressure caused by the consolidation of clayey soil should be taken into consideration. In this case the value of $k_{3, \text{доп}}$ is adopted as for the special combination of loads.

5.9. In calculating the stability of the slopes of dams the following cases should be discussed:

For the Downstream Slope:

a) The first estimated case (basic) in the headwater there is a normal back-thrust level (NPU), the drains are operating normally, there is established seepage in the embankment of the dam; if there is water in the tailwater its depth is taken as the maximal possible, but not over $0.2H$, where H is the rise of the crest of the dam over the bottom of the tailwater (with a great

depth of the water in the tailwater, in the calculation this depth should be assumed equal to $0.2 H$);

b) The second estimated case (special)--in the headwater is an augmented backwater level of the water (FPU) and the normal work of the drain is disturbed; the rest of the conditions are the same as in the first case.

For the Upstream Slope:

a) The first estimated case (basic)--the maximal possible reduction in the water level in the reservoir from the NPU is assumed, with the greatest possible rate; in this case the seepage forces occurring in the slope are taken into consideration;

b) The second estimated case (basic)--the water level in the headwater is at the lowest level, but not below $0.2 H_1$, where H_1 is the distance from the crest of the dam to the bottom in the headwater; the level of ground water in the dam embankment is assumed at the same level as the level of water in the reservoir;

c) The third estimated case (special)--the maximal possible reduction in the water level in the headwater is assumed, with the greatest possible rate, begun from the FPU; in this case the seepage forces occurring in the slope are taken into consideration.

Note. To be taken into consideration in estimating the stability of the slopes of earthfill dams is the seepage from the pond with its position in the period when the dam is filled, with regard to the wetted state of the soils of the slopes.

5.10. The stability of the elements of the structure of the dams under discussion should be ensured under all possible operating conditions, and also in the process of erecting the dam.

5.11. When estimating the stability of the slopes of the dams, the strength characteristics of the soils for the embankment of dams of classes III and IV should be assumed constant, and for dams of classes I and II--variable along the height depending on the stressed state of the soil in the zone of passage of the slide curves.

5.12. The settling of the embankment and foundation of the dam should be estimated to determine the required value of the construction rise of the dam and the amount of unevenness of the settling of different parts of it, as well as to define precisely the total amount of work for the structure of the dam.

The settling and the changes in time should be estimated for dams higher than 40 m, as well as for dams of a lesser height, noted in section 5.21. The settling of dams below 40 m high may be estimated by approximate relationships.

5.13. The settling of the dams should be estimated in each characteristic cross section of the dam along several verticals, passing in the elements of the dam with various materials (core, facing, prism, etc.).

The settling of the dams develops from the settling occurring as the result of the compacting of the material which forms the embankment of the dam and the settling of the foundation. The settling taking place by virtue of the compacting of the foundation and the embankment of the dam should be estimated in accordance with the norms for planning the foundations of hydraulic engineering structures.

5.14. The settling of earthfill and hydraulic fill dams, as well as of the impervious devices of earth dams which are specified to be made of clayey soil should be estimated with regard to the additional effect of pore pressure (sections 5.20-5.24), and with estimates of earth dams higher than 70 m --with regard to the stressed state of the structure (sections 5.25-5.26).

5.15. The settling of the supporting triangles of earth dams and the embankment of rockfill dams during construction and operation should be determined on the basis of the results of experimental studies of the compressibility of the soils with regard to their creep.

To reduce settling resulting from the crushing of rock in zones of the dam with high compressing stresses, with the appropriate justification, the density of the fill may be increased by filling the pore space with quarry fines (in the process of the rock filling).

Notes: 1. For dams of classes III and IV, the settling of the rock fill may be assumed as 3% of the height of the dam uncompacted and 1.5% when compacted by water by means of hydraulic excavators, and the settling of the hydraulic rock fill as 0.5% of the height of the dam.

2. For rockfill dams with a facing the rock fill should be especially dense within the limits of the upstream wedge of the dam.

3. To be taken into consideration in estimating the settlement of a dam is the fact that about 80% of the estimated settling of the rock fill takes place when the dam is being constructed, and the rest of the settling is completed during operation.

5.16. Horizontal displacements of dams should be evaluated on the basis of analogies of dams constructed under similar conditions and with a similar design. For preliminary evaluations of the horizontal displacements of the crest of a dam they should be assumed equal to the settling of the crest of the dam after the reservoir is filled.

Note. The possibility of cracks forming in the core of dams of classes I and II should be assessed on the basis of calculation.

5.17. When planning dams with a core, the deformations of the bank slopes must be taken into consideration.

5.18. The reinforcement slabs of the slopes of dams should be checked for resistance to the action of maximal wave pressure.

The maximal local pressure of the broken wave, and the distribution of the wave pressure along the slope should be determined in accordance with the normative document for planning hydraulic engineering structures exposed to waves and ice.

5.19. The stability of side prisms of earthfill dams with a core made from clayey soil should be estimated in consideration of the consolidation of the core.

5.20. The pressure in the pores of clayey soils (pore pressure of consolidation) occurring in the process of their compaction due to the external forces exerted on them and their own weight should be calculated in estimates of the stability of the slopes and the settling of earthfill and hydraulic earthfill dams and impervious devices (core, facing) of earth dams, the height of which is over 40 m.

5.21. The pore pressure from consolidation of the soil with estimates of dams with a height of under 40 m should be calculated in cases of erecting dams:

- a) With the fill or pouring of the soil in water;
- b) When the dams are erected from almost impervious soil;
- c) When they are erected on a foundation formed by clayey soils with a soft-plastic, flowing-plastic and flowing consistency.

5.22. The pore pressure in the clayey soil of the embankment, core, facing and foundation of earth and earthfill dams should be estimated when the coefficient of soil seepage is $k_s < (5-10)10^{-4}$ cm/sec and the degree of its moisture content is $G \geq 0.85$.

5.23. The pore pressure with consolidation of the soils should be determined by calculations according to the theory of compaction of an earth medium.

When the pore pressure is determined in the foundations and embankment of dams erected by pouring into water, as well as in the embankment of hydraulic fill dams, the earth medium may be considered a two-phase system.

5.24. When estimating the pore pressure due to consolidation of the soils in the cores of earth dams higher than 70 m, the stressed state of the structure should be taken into consideration in accordance with the requirements of sections 5.25 and 5.26.

5.25. The stresses in the embankment of earth or rockfill dams should be determined to calculate in subsequent estimates the pore pressure and the deformations.

5.26. The selection of materials for the respective zones of the dam and evaluation of the working conditions of the core (facing) at its contact with the rock should be made in consideration of the stressed state of the structure.

The stressed state should be estimated for earth and rockfill dams of classes I and II over 70 m high. The use of relationships of linear and nonlinear theory of elasticity or models of the granular medium is permissible in the estimates.

The active forces should be determined from the weight of the rock fill itself and the hydrostatic pressure of the water exerted on the dam.

In the cases mentioned in sections 5.12-5.17 and 5.20-5.24, it is compulsory to calculate the redistribution of the stresses in the embankment and the foundation of the dam.

Table of Correlations Between Certain Units of Physical Values, Subject to Elimination, and Units of the International System

(1) Наименование величин	(2) Единица			(3) Единица		(7) Соотношение единиц
	(3) подлежащая изъятию	(4) наименование	(5) обозначение	(6) наименование	(7) обозначение	
(12) Сила; нагрузка; вес	килограмм-сила тонна-сила грамм-сила	килограмм-сила тонна-сила грамм-сила	кгс тс гс	ньютон	Н	1 кгс \sim 9.8 Н \sim 10 Н 1 тс \sim 9.8 \cdot 10 ³ Н \sim 10 МН 1 гс \sim 9.8 \cdot 10 ⁻³ Н \sim 10 мН
(11) Линейная нагрузка Поверхностная нагрузка	килограмм-сила на метр килограмм-сила на квадратный метр	килограмм-сила на метр килограмм-сила на квадратный метр	кгс/м кгс/м ²	ньютон на метр ньютон на квадратный метр	Н/м Н/м ²	1 кгс/м \sim 10 Н/м 1 кгс/м ² \sim 10 Н/м ²
(17) Давление	килограмм-сила на квадратный сантиметр килограмм-сила на квадратный миллиметр килограмм-сила на квадратный дециметр	килограмм-сила на квадратный сантиметр килограмм-сила на квадратный миллиметр килограмм-сила на квадратный дециметр	кгс/см ² мм. вод. ст. мм. рт. ст.	паскаль	Па	1 кгс/см ² \sim 9.8 \cdot 10 ⁴ Па \sim 10 ⁵ Па 1 мм. вод. ст. \sim 9.8 Па \sim 10 Па 1 мм рт. ст. \sim 133.3 Па
(17) Механическое напряжение Момент продольной нагрузки; модуль сдвига; модуль объемного сжатия	килограмм-сила на квадратный сантиметр килограмм-сила на квадратный миллиметр килограмм-сила на квадратный дециметр	килограмм-сила на квадратный сантиметр килограмм-сила на квадратный миллиметр килограмм-сила на квадратный дециметр	кгс/см ² мм. вод. ст. мм. рт. ст.	паскаль	Па	1 кгс/см ² \sim 9.8 \cdot 10 ⁴ Па \sim 10 ⁵ Па 1 мм. вод. ст. \sim 9.8 Па \sim 10 Па 1 мм рт. ст. \sim 133.3 Па
(20) Момент силы; момент вращения	килограмм-сила-метр	килограмм-сила-метр	кгс \cdot м	джоуль-метр	Н \cdot м	1 кгс \cdot м \sim 9.8 Н \cdot м \sim 10 Н \cdot м
(23) Работа (энергия)	килограмм-сила-метр	килограмм-сила-метр	кгс \cdot м	джоуль	Дж	1 кгс \cdot м \sim 9.8 Дж \sim 10 Дж
(26) Количество теплоты	килокалория	килокалория	кал	джоуль	Дж	1 ккал \sim 4.2 Дж
(26) Мощность	килограмм-сила-метр в секунду калория в секунду килокалория в час	килограмм-сила-метр в секунду калория в секунду килокалория в час	кгс \cdot м/с кал/с ккал/ч	ватт	Вт	1 кгс \cdot м/с \sim 9.8 Вт \sim 10 Вт 1 л. с. \sim 735.5 Вт 1 ккал/ч \sim 4.2 Вт 1 ккал/ч \sim 1.16 Вт
(24) Удельная теплоемкость	калория на грамм-градус Цельсия	калория на грамм-градус Цельсия	кал/(г \cdot $^{\circ}$ С)	джоуль на килограмм-градус Цельсия	Дж/(кг \cdot К)	1 ккал/(г \cdot $^{\circ}$ С) \sim 4.2 Дж/(кг \cdot К) 1 ккал/(кг \cdot К) \sim 4.2 Дж/(кг \cdot К)
(24) Теплопроводность	калория в секунду на сантиметр-градус Цельсия	калория в секунду на сантиметр-градус Цельсия	кал/(с \cdot см \cdot $^{\circ}$ С)	ватт на метр-градус Цельсия	Вт/(м \cdot К)	1 ккал/(с \cdot см \cdot $^{\circ}$ С) \sim 420 Вт/(м \cdot К) 1 ккал/(с \cdot м \cdot $^{\circ}$ С) \sim 4.2 Вт/(м \cdot К)
(32) Коэффициент теплообмена (теплоотдачи); коэффициент теплопередачи	калория в секунду на квадратный сантиметр-градус Цельсия	калория в секунду на квадратный сантиметр-градус Цельсия	кал/(с \cdot см ² \cdot $^{\circ}$ С)	ватт на квадратный метр-градус Цельсия	Вт/(м ² \cdot К)	1 ккал/(с \cdot см ² \cdot $^{\circ}$ С) \sim 42 кВт/(м ² \cdot К) 1 ккал/(с \cdot м ² \cdot $^{\circ}$ С) \sim 1.16 кВт/(м ² \cdot К)

[Key on Following Page]

Key:

1. Designation of values
2. Unit
3. Subject to elimination
4. International system
5. Designation
6. Symbol
7. Correlation of units
8. Force; load; weight
9. Kilogram-force; ton-force; gram-force
10. Newton
11. Linear load; surface load
12. Kilogram force per meter; kilogram force per square meter
13. Newton per meter; newton per square meter
14. Pressure
15. Kilogram-force per square centimeter; millimeter of water column; millimeter of mercury column
16. Pascal
17. Mechanical stress; modulus of longitudinal elasticity; modulus of shear; modulus of volume compression
18. kilogram-force per square millimeter; kilogram-force per square centimeter
19. Pascal
20. Moment of force; coupling moment
21. Kilogram-force-meter
22. Newton-meter
23. Work (energy); Amount of heat
24. Kilogram-force-meter; calorie; kilocalorie
25. Joule
26. Power
27. Kilogram-force-meter per second; horse power; calories per second; kilocalories per hour
28. Watt
29. Specific heat
30. Calories per gram-degree centigrade; kilocalories per kilogram-degree centigrade
31. Joule per kilogram-Kelvin
32. Heat conductivity
33. Calories per second per centimeter-degree centigrade; kilocalories per hour per meter-degree centigrade
34. Watt per meter-kelvin
35. Coefficient of heat exchange (heat transfer); coefficient of heat transmission
36. Calories per second per square centimeter-degree centigrade; kilocalories per hour per square meter-degree centigrade
37. Watts per square meter-Kelvin

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